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ENGINEERING, INSTRUMENTATION, SYSTEMS
INTEGRATION & FLIGHT SUPPORT
FOR BALLOON OPERATIONS

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Final Report
1 February 1979 - 20 October 1981

15 January 1982

Approved for public release; distribution unlimited

AIR FORCE GEOPHYSICS LABORATORY
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
HANSOM AFB, MASSACHUSETTS 01731

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The work performed under this contract consisted of: conducting balloon flight operations from selected sites; integrating GEE instrumentation and flight safety equipment into balloon-borne payloads; providing engineering support for payload integration and integrity; fabricating, calibrating and repairing command control/telemetry equipment; analyzing data; and reporting flight results.		

FOREWORD

This document, the Final Technical Report, was prepared under Contract No. F19628-79-C-0081 for the Air Force Geophysics Laboratory (AFGL) of the Electronic Systems Division of the Air Force Systems Command. It was generated by the Physical Science Laboratory (PSL) at New Mexico State University (NMSU) as a documentary summary of the work accomplished and the information gained in the performance of the contract for "Engineering, Instrumentation, Systems Integration & Flight Support for Balloon Operations". This document is submitted in direct response to the requirements of the Contract Data Requirements List (CDRL), Sequence Nos. 103 and 104.

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ABBREVIATIONS

AAF	Army Air Field
AFB	Air Force Base
AFGL	Air Force Geophysics Laboratory
AK	Alaska
CDRL	Contract Data Requirements List
CY	Calendar Year
CZ	Panama Canal Zone
DID	Data Item Description
DOE	Department of Energy
GFE	Government-Furnished Equipment
MA	Massachusetts
NM	New Mexico
NMSU	New Mexico State University
NCAR	National Center for Atmospheric Research
NOAA	National Oceanic and Atmospheric Administration
ONRRR	Office of Naval Research Resident Representative
PSL	Physical Science Laboratory
SCADS	Sampler Control and Data System

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1. CONTRACT OBJECTIVE

The major objective of this work effort was to collect particulate and gaseous samples in the stratosphere by integrating electrical and mechanical hardware into a balloon-borne sampling system; then, launch the system into the stratosphere, collect the desired samples, recover the system, reduce the data, and prepare summary reports.

2. INTRODUCTION

The work effort under Air Force Contract No. F19628-79-C-0081 was an on-going stratospheric measurement program in which the Physical Science Laboratory (PSL) of NMSU has been involved since 1 October 1976, when PSL assumed this effort under contract No. F19628-77-C-0031. The first contract ended 31 January 1979, when the present one, No. F19628-79-C-0081, came into being. This report covers the period 31 January 1979 to 20 October 1981. Although the basic effort is in support of the Ash Can Program, PSL had an expanded role in conducting other efforts in the Atmospheric Measurement Program. During this period, PSL was more deeply involved in instrumentation development and fabrication and in the evolution of the Cassette Sampling System.

3. SCOPE

The PSL/NMSU supplied the necessary personnel, services, specified materials and engineering support for 63 balloon research flights conducted at Holloman AFB, NM, Albrook AAF, CZ, Howard AFB, CZ and Eielson AFB, AK. In support of this effort, PSL:

3.1 Operated and maintained (GFE) telemetry and command stations, performed payload preparation and integration, and acquired real-time recorded data.

3.2 Interfaced (GFE) flight safety and scientific tracking devices, parachute recovery systems, and command/control systems into the balloon

flight systems. Provided for the design, fabrication, testing, and installation of subsystems necessary to insure proper operation of the balloon flight systems.

3.3 Coordinated balloon flight instrumentation requirements for each operation. Maintained and calibrated scientific and command/control equipment. Provided technical interface between the AFGL contractor and government operational facilities. Completed flight documentation and facility-use agreements. Acted as a technical representative of AFGL when coordinating scientific experimentation and data acquisition with the scientists and engineers concerned.

4. TECHNICAL PROGRESS

During the contract period PSL conducted 63 flights and provided technical assistance for one other flight in support of the Atmospheric Measurements Program. Of the 63 flights, eight were conducted from Eielson AFB, AK, five were conducted from Albrook AAF, CZ and three from Howard AFB, CZ. The remaining 47 were conducted at Holloman AFB, NM. To accomplish these flights, PSL calibrated equipment, provided technical interface, assembled payloads, rigged parachutes, conducted flight operations, directed aerial-catch recovery missions, monitored ground recovery activities, provided coordination between participating agencies, collected real-time data, made data reductions, packed and shipped equipment, set up remote operational sites, performed site coordination and completed flight documentation and reports. The flights flown, analyses of failures, and samples collected are logged in Tables I, II, III and IV. In addition to the normal flight operations, PSL was involved in several other work and development efforts related to the Atmospheric Measurements Program:

- First, during the February-April 1979 period, new cables were manufactured and parts procured for additional SCADS-2 units. Because of a change in direction, no more units were built as SCADS-2 was to evolve into SCADS-3.

Table 1 - Contract Flight Log - 09 February 79 to 02 November 81

Line	Flight No.	Date	Alt. (Kft) ($\times 10^6 ft^3$)	Bin Size	Type Sampler and Experiment	Remarks
1.	H79-06/H-143X	9 Feb 79	65	0.804	NCAR Gondola, Chlorine	Success
2.	H79-08/H-144X	23 Feb 79	97	2.010	NCAR Cassette, HCl	Success
3.	H79-10/P-158	14 Mar 79	80	0.516	Dual DFS & C-14, Radioactive Nuclides	Success
4.	H79-11	15 Mar 79	66	0.274	AFOL Cryogenic Sampler, Whole Air	Success
5.	H79-12/P-159	16 Mar 79	105	1.840	Air Ejector & C-14, Radioactive Nuclides	Success
6.	H79-13/P-160	19 Mar 79	70	0.274	Dual DFS & C-14, Radioactive Nuclides	Success
7.	H79-14	20 Mar 79	98	2.900	AFOL Cryogenic Sampler, Whole Air	Success
8.	H79-16/H-145	6 Apr 79	70	0.353	Dual DFS & C-14, Radioactive Nuclides	Success
9.	H79-17/H-146	17 Apr 79	80	0.628	Dual DFS & C-14, Radioactive Nuclides	Success
10.	H79-18/H-147	21 Apr 79	105	1.840	Air Ejector & C-14, Radioactive Nuclides	Success
11.	H79-19/H-148X	24 Apr 79	115	4.890	NCAR Cassette, HCl	Success
12.	H79-22/A-147	9 Jun 79	80	0.516	Dual DFS & C-14, Radioactive Nuclides	Success
13.	H79-23/A-148	14 Jun 79	105	1.840	Air Ejector & C-14, Radioactive Nuclides	Success
14.	H79-25/A-149	15 Jun 79	70	0.274	Dual DFS & C-14, Radioactive Nuclides	Bin failed in Launch Arm
15.	H79-26/A-150	16 Jun 79	70	0.274	Dual DFS & C-14, Radioactive Nuclides	Success
16.	H79-28/A-151X	18 Jun 79	135	10.600	HV3K, Radioactive Nuclides	Success
17.	H79-29	19 Jun 79	135	10.600	Emulsion Plate, Cosmic Rays	Success
18.	H79-35/H-149	17 Jun 79	70	0.274	Dual DFS & C-14, Radioactive Nuclides	Success
19.	H79-36/H-150	24 Jul 79	80	0.628	Dual DFS & C-14, Radioactive Nuclides	Success
20.	H79-37/H-151	26 Jul 79	105	1.840	Air Ejector & C-14, Radioactive Nuclides	Partial, PR-3 Failed
21.	H79-38/H-152X	28 Jul 79	115	4.890	NCAR Cassette, Atmospheric Constituents	Partial, Cassette Did Not Seal Filter
22.	H79-40	21 Aug 79	107	3.690	U of Denver Gondola, IR Solar Spectrum	Success
23.	H79-44	13 Sep 79	123	3.020	U of Wyoming Gondola, Sun Photometer Measurements	Success, Gondola Destroyed
24.	H79-47/H-153X	27 Sep 79	115	4.890	NCAR Cassette, Stratospheric Constituents	Partial, Cassette Did Not Seal Filter
25.	H79-48/H-154	1 Oct 79	90	1.110	DOE Cassette, DFS, C-14, Radioactive Nuclides; C-14 & DFS/Cassette, Intercomparison	Success, PR-3 Failed
26.	H79-51	10 Oct 79	107	5.030	U of Denver Gondola, IR Solar Spectrum	Success
27.	H79-52/H-155	16 Oct 79	70	0.274	Dual DFA & C-14, Radioactive Nuclides	Success
28.	H79-54/H-156	19 Oct 79	80	0.516	Dual DFS & C-14, Radioactive Nuclides	Success
29.	H79-58/H-157X	6 Nov 79	35	0.145	Aerial Recovery Test of MK-8 Parachute System	Success
30.	H79-59/H-158X	10 Nov 79	35	0.145	Aerial Recovery Test of MK-5 Parachute System	Success
31.	H80-08	10 Feb 80	113	3.690	U of Denver Gondola, Solar Measurements	Success
32.	H80-10/P-161	11 Mar 80	70	0.274	Dual DFS & C-14, Radioactive Nuclides	Success
33.	H80-11/P-162	12 Mar 80	80	0.516	Dual DFS & C-14, Radioactive Nuclides	Success
34.	H80-12/P-163	13 Mar 80	90	0.859	Dual DFS & C-14, Radioactive Nuclides	Success
35.	H80-15/H-159	4 Apr 80	90	1.110	DOE Cassette, DFS, C-14, & U of MIA; Radioactive Nuclides, Aerosols, & Whole Air (Tritium)	No Cassette
36.	H80-16/H-160	10 Apr 80	80	0.628	DOE Cassette, DFS, C-14, & U of MIA; Radioactive Nuclides, Aerosols, & Whole Air (Tritium)	Success

Table I - Contract Flight Log - 09 February 79 to 02 November 81 (Concluded)

Line	Flight No.	Date	Alt. (Kft)	Bin Size ($\times 10^6 \text{ ft}^3$)	Type Sampler and Experiment		Remarks
					DOE Cassette, DFS, & C-14; Radioactive Nuclides & Aerosols	AFOL TRIWAS Sampler, Whole Air	
37.	H80-17/H-161	14 Apr 80	70	0.355	DOE Cassette, DFS, & C-14; Radioactive Nuclides & Aerosols		Success
38.	H80-19	28 Apr 80	70	0.628	AFOL TRIWAS Sampler, Whole Air		Success
39.	H80-24/A-152	7 Jun 80	70	0.274	Dual DFS, C-14, & U of MIA; Radioactive Nuclides & Whole Air (Tritium)		Success
40.	H80-25/A-153	8 Jun 80	80	0.516	Dual DFS, C-14, & U of MIA; Radioactive Nuclides & Whole Air (Tritium)		Success
41.	H80-26/A-154	9 Jun 80	90	0.859	Dual DFS, C-14, & U of MIA; Radioactive Nuclides & Whole Air (Tritium)		No Whole Air
42.	H80-28/H-162	23 Jul 80	80	0.628	DOE Cassette, DFS, C-14, & U of MIA; Radioactive Nuclides & Whole Air (Tritium)		Success
43.	H80-29/H-163	25 Jul 80	70	0.355	DOE Cassette, DFS, C-14, & U of MIA; Radioactive Nuclides & Whole Air (Tritium)		No DFS
44.	H80-30/H-164	29 Jul 80	90	1.110	DOE Cassette & U of MIA; Volcanic Ash, Sulfur & Whole Air (Tritium)		Success
45.	H80-35/H-165	9 Oct 80	90	1.110	DOE Cassette, C-14, & U of MIA; Radioactive Nuclides, Whole Air (Tritium)		Success
46.	H80-36/H-166	16 Oct 80	70/80	0.628	DOE Cassette, DFS, C-14, U of MIA; Radioactive Nuclides, Whole Air (Tritium)		No DFS
47.	H80-37/H-167X	3 Nov 80	88	2.010	NCAR Gondola, Chlorine Measurements		Bin Burnt
48.	H80-39/H-168X	11 Nov 80	88	2.900	NCAR Gondola, Chlorine Measurements		Success
49.	H81-02	9 Mar 81	111	3.690	U of Denver Gondola, Positive ION Measurements		Success
50.	H81-04	19 Mar 81	130	11.620	U of Denver Gondola, Solar IR Measurements		Success
51.	H81-05	23 Mar 81	110	9.130	U of Denver Gondola, Solar UV Measurements		Success
52.	H81-06/H-169	1 Apr 81	70/80	0.628	DOE Cassette, DFS, & C-14; Radioactive Nuclides		Success
53.	H81-07/H-170	5 Apr 81	90	1.110	DOE Cassette, DFS, & C-14; Radioactive Nuclides		Success
54.	H81-08	9 Apr 81	115	3.690	U of Denver Gondola, Solar Irradiance Measurements		Success
55.	H81-17/H-171X	25 Jun 81	80	0.516	DOE Cassette & SCADS III Test, Radioactive Nuclides		Success
56.	H81-18/H-172	7 Jul 81	70/80	0.628	DOE Cassette, DFS, & C-14; Radioactive Nuclides		Success
57.	H81-19/H-173	13 Jul 81	90	1.110	DOE Cassette, DFS, & C-14; Radioactive Nuclides		Bin Failed Launch Arm
58.	H81-20/H-174	14 Jul 81	90	1.110	DOE Cassette, DFS, & C-14; Radioactive Nuclides		Bin Failed at Release
59.	H81-21/H-175	14 Jul 81	90	1.110	DOE Cassette, DFS, & C-14; Radioactive Nuclides		Success
60.	H81-28/H-176X	7 Oct 81	120	11.620	NCAR Gondola, Chlorine Measurements		Bin Failed at Release
61.	H81-29/H-177X	8 Oct 81	120	11.620	NCAR Gondola, Chlorine Measurements		Success
62.	H81-31/H-178	27 Oct 81	90/60	2.010	DOE Cassette, DFS, & C-14; Radioactive Nuclides & Sulfides		Cassette Failed
63.	H81-33/H-179	2 Nov 81	80/50	0.803	DOE Cassette, DFS, & C-14; Radioactive Nuclides & Sulfides		Success

Table II - Analyses of Flight Failures

FLIGHT NO.*	DATE	REASON FOR FAILURE*	MODE**	SAMPLE/DATA LOST
H79-25/H-149	15 Jun 79	Balloon Damaged in Launch Arm Because of Winds	f	Two DFS & C-14
H79-37/H-151	26 Jul 79	PR-3 Flowsensor Failed	d(1)	Supporting Flow Data
H79-38/H-152X	28 Jul 79	Cassette Failed to Seal Filter & Damaged PR-3 Flowsensor	d(1)	Supporting Flow Data
H79-40	21 Aug 79	Balloon Failed to Reach Proper Altitude	a	High Altitude Experiment
H79-47/H-153X	27 Sep 79	Cassette Failed to Seal Filter & Damaged PR-3 Flowsensor	d(1)	Supporting Flow Data
H79-48/H-154	3 Oct 79	PR-3 Flowsensor Failed	d(1)	Supporting Flow Data
H80-15/H-159	4 Apr 80	Cassette Did Not Function	d(1)	Cassette Sample
H80-26/H-154	9 Jun 80	IG Failed; Allowed UTNT Doors & U of NIA Valve to Open at Aerial Engagement	e(1)	U of NIA Tritium Sample
H80-29/H-163	25 Jul 80	Polyflo Cap Cracked; UTNT Doors Did Not Open	d(1)	DFS Sample
H80-37/H-167	3 Nov 80	Balloon Burst	a	Chlorine
H81-19/H-173	13 Jul 81	Balloon Failed Launch Arm	a	DFS, C-14, & Cassette
H81-20/H-174	14 Jul 81	Balloon Failed at Release	a	DFS, C-14, & Cassette
H81-28/H-176X	7 Oct 81	Balloon Failed at Release	a	Chlorine
H81-31/H-178	27 Oct 81	Cassette Sampler Failed to Activate; Dragging Filter Drum	d(1)	Cassette

MODE** SUMMARY	NO. SAMPLES LOST
a) Balloon Failure	9
b) Human Error	0
1) Mechanical	0
2) Electrical	0
3) Judgement	0
c) Impact Damage	0
d) Mechanical	3
1) Ground Support Equipment	0
2) Flight Support Equipment	3
e) Electrical	1
1) Ground Support Equipment	1
2) Flight Support Equipment	0
f) Meteorological	3
TOTAL	16

*Flights failing to collect either a valid sample or sufficient supporting data
 **Failure Classification

Table III Sampling Summaries, by CY

FLIGHTS	<u>CY 1979</u>	<u>TOTAL</u>	<u>SUCCESS</u>	<u>FAILED</u>	<u>% SUCCESS*</u>
DFS		23	21	2	91
C-14		16	15	1	94
Cassette DOE		1	1	0	100
Cassette NCAR		4	4	0	100
Chlorine		1	1	0	100
AFGL/TRIWAS		2	2	0	100
U of Denver		2	2	0	100
U of Wyo		1	1	0	100
Air Ejector		4	4	0	100
AFGL/Filz		1	1	0	100
HV3K		1	1	0	100
Parachute Test		2	2	0	100
FLIGHTS	<u>CY 1980</u>	<u>TOTAL</u>	<u>SUCCESS</u>	<u>FAILED</u>	<u>% SUCCESS*</u>
DFS		18	16	2	89
C-14		12	12	0	100
Cassette DOE		8	7	1	88
U of MIA (Tritium)		10	9	1	90
Chlorine		2	1	1	50
AFGL/TRIWAS		1	1	0	100
U of Denver		1	1	0	100
FLIGHTS	<u>CY 1981</u>	<u>TOTAL</u>	<u>SUCCESS</u>	<u>FAILED</u>	<u>% SUCCESS*</u>
DFS		8	6	2	75
C-14		8	6	2	75
Cassette DOE		9	6	3	67
Chlorine		2	1	1	50
U of Denver		4	4	0	100

* A sample is considered a success when enough material is collected and there are enough supporting data to make a valid statement or valid real-time measurements are made.

Table IV - Sampling Summary, Contract (3 CYs)

FLIGHTS	TOTAL	SUCCESS	FAILURE	% SUCCESS*
	63	58	5	92%
● AFGL/TRIWAS	3	3	0	100%
● AFGL/Filz	1	1	0	100
● Cassette NCAR	4	4	0	100
● HV3K	1	1	0	100
● Parachute Test	2	2	0	100
● Air Ejector	4	4	0	100
● U of Denver	7	7	0	100
● U of Wyoming	1	1	0	100
● C-14	36	33	3	92
● U of MIA (Tritium)	10	9	1	90
● DFS	49	43	6	88
● Cassette DOE	18	14	4	78
● Chlorine	5	3	2	60
	141	125	16	89%

* A sample is considered a success when enough material is collected and there are enough supporting data to make a valid statement or valid real-time measurements are made.

- Later in the year, August-October 1979, a pressure/temperature system was developed to provide real-time data concerning the gas dynamics during sampling. This system monitored gas pressure and temperature in the spheres and at the orifice. These data were very useful in determining consumption rates and making operational decisions. Also, an unknown anomaly in the regulated pressure was detected using this system.
- Parallel with other efforts was a program to extend the life of the PR-3 flow sensors by special lubrication, reworking the bearing mount assembly and installing new bearings. This effort is approximately 50% completed, after using available funding.
- As the MK-8 parachute system was brought into use, a new sleeve was designed and manufactured that contained all exterior cables in a slip sleeve. This sleeve was easier to rig and use than the previous model that had been used.
- During the October 1979 series, the 12-channel Raven command receiver was incorporated into the electronic package.
- The intercomparison work between the DFS and Cassette was initiated in October 1979 on Flight H79-48/H-154. This effort continued into 1980.
- In conjunction with the Alaskan series in June 1980, PSL set up and operated the TRADAT system. This system was used for balloon positioning in place of the normal radiosonde methods.
- At the end of CY80, as the complexity of the flights increased and the need for more commands and data channels grew, PSL began development and fabrication of the SCADS-3 instrumentation system. This first unit was flown successfully in June 1981 and flew operationally during the July 1981 sampling series. This unit was destroyed by a free fall during the October 1981 series. A new unit has not been fabricated.

- Also during 1981, PSL developed an interface system that fed real-time data from the SCADS system into the HP-85 computer. This system removed the need for hand data reduction and greatly reduced the administrative work load of the PSI, Balloon Launch Group.
- As the Ash Can Sampling Program evolved into the Cassette System and as many other measurement flights were conducted by PSL, the complexity of flight operations increased dramatically. These flights required controlled descents, controlled profiles, long durations, larger balloons, and forward command control systems. In addition to the increased complex effort at Holloman AFB, PSL continued to deploy to remote sites in Panama and Alaska.

5. SUMMARY OF WORK PERFORMED

- Conducted 63 balloon missions which included:
 - Calibration of Equipment
 - Assembling Payloads
 - Rigging Parachutes
 - Conducting Flight Operations
 - Monitoring Recovery Activities
 - Coordination between using and controlling agencies
 - Collecting Data
 - Reducing Data
 - Flight Reporting
- Provided technical assistance for one balloon flight.
- Fabricated and flight-tested one SCADS-3 unit.
- Developed a pressure/temperature sensoring system.
- Installed new bearings and lubricated the PR-3 flow sensors. (50% complete.)
- Developed a new rigging sleeve for the MK-8 parachute system.
- Integrated the 12-channel Raven command system.

- Set up and operated the TRADAT system.
- Fabricated and tested the SCADS-3 system.
- Interfaced SCADS-2 data system with the HP-85.
- Attained skills in conducting complex balloon flight operations.
- Deployed the flight operations to Panama and Alaska which required:
 - Setting up command and control stations
 - Setting up data acquisition stations
 - Controlling balloon flights from a field station
 - Planning and controlling the logistics and material to make these sites functional

6. CONTRACT MATTER

6.1 In response to Contract Data Item Description (DID) No. DI-S-3591/A/M, as modified, following is a listing, in alphabetic order, of various professional personnel who contributed to the research reported herein:

Thomas E. Ashenfelter/NOAA	Dr. Frank P. Hudson/DOE
Stewart P. Bean/PSL	Dr. Robert Leifer/DOE
Robert H. Cordella, Jr./NOAA	John J. Maure/PSL
Wade L. Craddock/PSL	George Nolan/AFGL
Thomas A. Danaher/AFGL	S. B. Seagraves/PSL
Thomas J. Gross/DOE	Elger P. Stauber/PSL
John R. Ground/PSL	D. N. Wofford/PSL

6.2 The only previous AFGL/PSL contract related to and preceding the work herein summarized was the following:

- Contract No. F19628-77-C-0031 1 Oct 76 - 31 Jan 79

No previously produced publications or articles resulted from AFGL's sponsorship of this Contract No. F19628-79-C-0081. Only such formal documentation as was specified by the Contract Data Requirements List has been generated by PSL and submitted to required distribution.

6.3 Contract funds remaining as of 30 November 1981 amounted to \$31,957.89. Included in this amount is a money reserve for the preparation and distribution of this Final Technical Report, in both its "Draft Manuscript" form and in "Reproducible Copy" form. Also to be reserved is a pending money-consideration for extending the termination date of this contract to the beginning date of follow-on Contract No. F-19628-82-C-0013, with a term of 1 November 1981 to 31 October 1983.

6.4 No patents resulted from PSL participation in this contract. See PSL Final Patent Report letter to ONRRR dated 1 October 1981.

6.5 No equipment, GFE or other, was acquired during the contract period. See PSL Final Inventory of Government Property, forwarded to ONRRR on 8 December 1981.

Distribution

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